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OFFICE OF CHEMICAL SAFETY
AND POLLUTION PREVENTION

MEMORANDUM

SUBJECT: Benefits of Neonicotinoid Insecticide Use in Cucurbit Production and Impacts of Potential Risk Mitigation

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SUMMARY

The Environmental Protection Agency (EPA) is evaluating and considering whether potential risk mitigation measures are needed to address risk concerns to pollinator and aquatic invertebrate health associated with the use of nitroguanidine neonicotinoid insecticides: clothianidin, dinotefuran, imidacloprid, and thiamethoxam on cucurbit crops. Risks to pollinators are present when these chemicals are used from pre-bloom to harvest on cucurbit crops via foliar or soil-applied methods. Pollinator and aquatic invertebrate exposure could be reduced by:

- reducing the maximum single application rate for each neonicotinoid;
- reducing the maximum number of applications;
- prohibiting applications during the vining to harvest (pre-bloom and bloom-time) period;
- prohibiting foliar applications; and
- requiring drift mitigation measures.

These proposed measures might reduce residues in areas adjacent to treated fields, including adjacent water bodies and pollinator forage.

This memorandum outlines the benefits of neonicotinoid usage in cucurbit crops (cantaloupe, watermelon, squash, cucumber, and pumpkin) from crop emergence to harvest in the Western, Southern, and North/Midwest production regions. Potential impacts are estimated herein considering a restriction of soil applied and foliar applications of these active ingredients. BEAD concludes that most neonicotinoid applications occur during the emergence-to-vining period (79% of all acres treated) instead of the vining-to-harvest crop stage (21% of all acres treated) encompassing pre-bloom and bloom-time periods. Therefore, 21% of all treated acres would be affected by pre-bloom and bloom-time application restriction.

Across the growing season, neonicotinoids provide high benefits to cucurbit growers as a soil-applied systemic insecticide for protection against disease-vectoring insect pests and as a foliar knockdown. The Agency is considering an application rate reduction as one potential option to mitigate risks to bees, and BEAD has conducted an application rate reduction analysis to inform these considerations. Most cucurbit growers surveyed were applying neonicotinoids at or near the maximum single application limits. Nationally, impacts from neonicotinoid application rate reductions arise because neonicotinoid users would likely switch to alternative insecticides for control of key target pests (whiteflies, aphids, and cucumber beetle), such as cyantraniliprole, acetamiprid, and bifenthrin. These alternatives may be used to achieve similar control as the neonicotinoids, based on extension recommendations, thus, yield effects are not anticipated, but pest control costs are likely to increase. However, BEAD may have underestimated the likelihood of increased disease pressure from insect-vectored pathogens transmitted by whiteflies that are controlled by systemic insecticides when systemic alternatives to the neonicotinoids are not available or labeled use maxima has been exhausted. Additionally, usage of pyrethroid chemistries (e.g., bifenthrin) may flare mites, further increasing control costs.

Due to resistance cases documented in the South and West production regions, application rate reductions for each of the neonicotinoids may equate to cancellation of these chemistries for growers requiring high rates. Rate reductions may hasten the development of resistance to these active ingredients nationwide.

Eliminating foliar applications of neonicotinoids will have a severe impact on growers. Approximately 38% of all acres treated with neonicotinoids were done foliarly, especially from emergence to harvest, when insect pests during the latter stages of cucurbit growth can be troublesome. Growers risk disease spread, crop damage, or another insect-borne malady without the use foliar applied neonicotinoids. Growers would have little option but to use alternative chemistries such as organophosphates and pyrethroids.

INTRODUCTION

FIFRA Section 3(g) mandates that EPA periodically review the registrations of all pesticides to ensure that they do not pose unreasonable adverse effects to human health and the environment. This periodic review is necessary considering scientific advancements, changes in policy, and changes in use patterns that may alter the conditions underpinning previous registration decisions. In determining whether effects are unreasonable, FIFRA requires that the Agency consider the risks and benefits of any use of the pesticide.

EPA has identified potential ecological risks of concern associated with the use of nitroguanidine neonicotinoids in cucurbit production. Pollinators, especially managed bees, may be exposed to residues from neonicotinoid applications conducted prior to bloom and while the crop is blooming. Soil applications result in lower exposure to pollinators than do foliar applications but due to the systemic nature of these chemistries, residues may persist in nectar and pollen. Use of neonicotinoids may also result in chronic risks to aquatic invertebrates. These risks increase if there are multiple applications over the season because concentrations in water can increase with each application. Foliar applications may result in higher concentrations than soil applications due to the greater potential for residues to drift from the field directly into water.

EPA is considering potential measures to reduce exposure to pollinators and aquatic invertebrates. One potential measure would be to reduce allowable single application rates; chronic exposure to aquatic invertebrates may also be reduced by lowering the allowable annual application rates. Prohibiting foliar applications could also reduce exposure, especially to pollinators. Pollinator exposure could be reduced by prohibiting applications prior to and during bloom. Drift reduction measures, including requiring low boom height or larger droplets might reduce residues in areas adjacent to treated fields, including adjacent water bodies and pollinator forage.

To help inform the mitigation decision, this memorandum presents information on the usage of clothianidin, dinotefuran, imidacloprid, and thiamethoxam in cucurbits, including usage at different crop stages. The assessment describes the benefits of neonicotinoid use in cucurbit production and analyzes the impacts of potential mitigation measures.

METHODOLOGY

EPA assesses the benefits of neonicotinoids by comparing the existing situation in which a cucurbit producer uses neonicotinoids to the counterfactual situation in which he or she cannot use neonicotinoids or is more limited in the use of the neonicotinoids. In the absence of neonicotinoids, users will likely switch to alternative insecticides. Impacts of the loss of neonicotinoids may arise due to the higher cost and/or lower efficacy of these alternatives; that is, the benefits of neonicotinoids may be lower production costs and/or higher yields or quality. Restrictions on the use of neonicotinoids may have similar impacts. These impacts may be quantified in per-acre monetary terms.

Cucurbits include cucumber, squash, pumpkins, cantaloupe, and watermelon. Given similarities in production, these crops are largely analyzed together; differences are noted where important. The unit of analysis for this assessment is an acre of a cucurbit crop treated with a neonicotinoid insecticide via foliar sprays. BEAD first identifies the primary pests targeted by growers when using a neonicotinoid. Data for this purpose comes from pesticide market research data (MRD) collected through annual surveys of growers conducted by a leading private research firm. The survey information is collected following a statistically valid approach. Additional information is found in state university extension recommendations. Alternative pest control options are identified using these sources.

The most likely methods of control growers would use to replace neonicotinoids are identified using best professional judgement based on biological considerations and economic theory. For example, a less expensive option would not generally be considered a likely option to replace the use of a neonicotinoid because growers are assumed to minimize costs to maximize profits; hence, if a less expensive insecticide provides the same benefits as the neonicotinoid, a farmer would not be using the neonicotinoid. However, less expensive options might be employed multiple times to achieve the same level of control as a neonicotinoid, at an increase in cost, or growers may incur some loss in yield or quality, measured as a reduction in price received, due to less effective pest control. Information on chemical and application costs is available from the market survey data as well as crop budgets developed by state university extension programs. Information on comparative performance of neonicotinoids and other insecticides come from research trials and published usage recommendations by various entities including registrants and state universities.

The increased per-acre cost and/or reduced revenue per acre is then placed in the context of grower income to characterize the impacts of restrictions/benefits of the neonicotinoids. BEAD uses net operating revenue, defined as gross revenue per acre less operating costs per acre, as the measure of income. Data from USDA National Agricultural Statistics Service (NASS) are used to calculate average gross revenue per acre. State university extension estimates are used to calculate operating costs. Fixed costs, such as land rent, equipment depreciation, and overhead costs, are not included because allocating these costs on a per-acre basis is complex due to the variation in farm size and diversity in farm production. While often included in budgets for major commodities, fixed costs are often not included in budgets for specialty crops like vegetables. For consistency across use sites, BEAD relies on measures of net operating revenue, acknowledging that this overstates grower income and will underestimate the impact of restrictions on pesticide use, at least on an affected acre.

Given the potential options for mitigation, the analysis considers the benefits of neonicotinoid insecticides at different stages of crop growth. Refinements are also made to assess impacts in different regions of the country.

OTHER ASSESSMENTS AND COMMENTS

As part of the public comment period following publication of the risk assessment, several assessments were submitted to EPA. Dr. Paul Mitchell from AgInfomatics, LLC, (EPA-HQ-OPP-2011-0920-0105) assessed the benefits of neonicotinoid insecticides in U.S. agriculture (Mitchell, 2015); however, cucurbits were omitted from the 9-report assessment. In general, the assessment estimated the aggregate economic benefits at about $4 billion annually. The assessment states that the benefits of lower application costs (for neonicotinoids) to be about $925 million, but the amount of cost-savings attributed to cucurbits were not determined.

EPA received several comments related to neonicotinoid uses for cucurbits. Generally, the comments (EPA-HQ-OPP-2008-0844-1129, -1151, -1529, and -0874) attested to the neonicotinoids' benefits, including: contribution to an integrated pest management program, fit into insect resistance management programs, short pre-harvest intervals and re-entry times, treatment flexibility, efficacy on aphids and whiteflies, and "soft" on beneficial insects.

BEAD concurs that the neonicotinoids are a part of many integrated pest management and insect resistance management plans. Within the document, BEAD addresses the other concerns in the **BENEFITS OF NEONICOTINOIDS** section below. The short pre-harvest interval, re-entry times, and "softness" to beneficial insects are outside the purview of this document addressing the proposed risk mitigations.

EPA also received other general comments, but those comments did not address any of the proposed mitigation or address non-cucurbit uses.

CUCURBIT PRODUCTION

Table 1 presents the national annual average production for cucurbits covering the period 2013 – 2017, per USDA NASS survey data (USDA/NASS, 2018). NASS surveys cover states accounting for at least 80% of production. Overall, 401,000 acres of cucurbits are harvested, on average, with cucumbers and watermelon the largest in terms of acreage (Table 1). There are some regional differences in production, for example, watermelon is grown throughout the country while cantaloupe production is concentrated in the West. Pumpkin and squash are grown primarily in the North/Midwest states; pumpkin is particularly concentrated in the Northeast/Midwest states. Fresh cucumber is mostly grown in the Southeast, including Florida and Georgia; pickling cucumber is mostly grown in Michigan and Wisconsin. (USDA/NASS, 2018)

Table 1. Acreage, Production, and Value of Cucurbits, 2013 – 2017 Annual Averages.

State	Acres Harvested	Production (1000 cwt)	Yield (cwt/acre)	Total Value ($1,000)	Gross Revenue ($/acre)
Cantaloupe	58,800	14,800	252	$281,923	$4,800
Cucumber [1]	122,000	18,000	148	$370,246	$3,040
Pumpkin [2]	70,400	16,200	231	$203,392	$2,890
Squash	37,600	6,000	159	$185,054	$4,920
Watermelon	112,000	37,000	330	$519,391	$4,620
US total	401,000	92,100	230	$1,560,006	$3,990
West [3]	91,000	27,000	297	$482,099	$5,300
South [4]	172,000	38,100	221	$698,095	$4,060
North/Midwest [5]	138,000	26,700	194	$363,392	$2,640

Source: USDA/NASS, 2018. Numbers may not add up due to rounding.

1 Includes fresh and pickling cucumber.

2 Data for 2016-2017 only; NASS added 10 states, accounting for over 25,000 acres, according to the survey.

3 Arizona, California, Colorado, Oregon, and Washington.

4 Alabama, Arkansas, Florida, Georgia, Mississippi, North Carolina, South Carolina, Tennessee, Texas, and Virginia.

5 Delaware, Illinois, Indiana, Maryland, Michigan, Minnesota, Missouri, New Jersey, New York, Ohio, Pennsylvania, and Wisconsin.

The total value of cucurbit production averages almost $1.6 billion annually; watermelon alone accounts for almost one-third of the total value (Table 1). Pickling cucumber accounts for almost 70% of the cucumber acreage, but less than half the total value of cucumber production (USDA/NASS, 2018). Gross revenue is lowest in pumpkin production, which is primarily for processing or jack o' lanterns. Regionally, Western states produce the highest yields and obtain the highest average gross revenue per acre. Northern states have lower yields and lower gross revenue per acre; in addition to lower yields, the lower revenue is also due to a greater share of production in pickling cucumber (Table 1).

There is much variation in growth of cucurbits not only due to the variation between types of cucurbits (e.g. watermelons, cucumbers), but also because there are numerous varieties within each cucurbit type. In general, cucurbits may be direct-seeded or transplanted. Transplants will be ready for harvest about a week earlier than seeded plants. The first vine begins shortly after emergence and about a month later, more vines will grow. Flowering typically includes both male and female flowers that occur about two weeks after most of the vines have set. However, varieties may have a distinct bloom time, so fruit is mature at one time, or they may have continuous bloom. (Barker 2018; Maynard 2007; Schultheis, et al. 2000).

NEONICOTINOID USAGE IN CUCURBITS

Based on information from the available pesticide market research data (2013-2017), imidacloprid is the primary neonicotinoid used on cucurbits. Thiamethoxam is used consistently across the different cucurbits, at about five to ten percent crop treated (PCT)[1]. Dinotefuran usage is relatively low, except for usage on cantaloupe and squash, and clothianidin usage is largely negligible. See Table 2.

Table 2. Annual Average Neonicotinoid Usage on Cucurbits, 2013 – 2017

Crop Active Ingredient	**Percent Crop Treated[1]**	**Total Acres Treated[2]**	**Pounds Applied**	**Application Rate (lbs. a.i./acre)**	**Number of Times Applied**
Cantaloupe		**53,000**	**13,600**		
Clothianidin	Negligible				
Dinotefuran	23%	19,500	4,200	0.214	1.5
Imidacloprid	49%	27,700	8,600	0.309	1.0
Thiamethoxam	10%	5,600	900	0.151	1.0
Cucumber		**33,600**	**6,400**		
Clothianidin	Negligible				
Dinotefuran	4%	8,200	1,400	0.172	1.8
Imidacloprid	11%	14,000	4,000	0.286	1.2
Thiamethoxam	10%	12,000	1,200	0.099	1.1
Pumpkin		**18,500**	**3,300**		
Clothianidin	2%	1,500	100	0.079	1.1
Dinotefuran	Negligible				
Imidacloprid	12%	10,300	2,600	0.251	1.2
Thiamethoxam	4%	5,400	400	0.076	1.3
Squash		**20,000**	**3,800**		
Clothianidin	2%	1,400	100	0.082	1.4
Dinotefuran	9%	5,700	1,000	0.184	1.5
Imidacloprid	19%	10,000	2,300	0.232	1.2
Thiamethoxam	5%	3,100	300	0.100	1.4
Watermelon		**47,800**	**9,800**		
Clothianidin	Negligible				
Dinotefuran	3%	3,500	500	0.149	1.0
Imidacloprid	23%	38,300	8,500	0.223	1.5
Thiamethoxam	6%	8,100	1,100	0.134	1.2
Cucurbits		**173,000**	**37,000**		
Clothianidin	1%	5,700	400	0.075	1.3
Dinotefuran	7%	36,600	7,100	0.195	1.5

[1] PCT = Base Acres Treated ÷ Crop Area Grown. Or, the number of physical acres treated at least once, divided by the number of acres the crop is grown.

Imidacloprid	21%	100,000	26,000	0.259	1.2
Thiamethoxam	7%	30,300	3,400	0.112	1.2

Source: MRD, 2013 – 2017. Does not include acres planted with treated seed. Numbers may not add up due to rounding.

1 Percent crop treated (PCT) is calculated as base acres treated, the number of acres treated at least once with an active ingredient, divided by crop acreage. PCT with any neonicotinoid may be less than the sum of the individual chemical PCTs since more than one neonicotinoid may be applied to the same acre.

2 Total acres treated account for acres treated more than once with an active ingredient.

Cucurbit growers treated 173,000 acres with neonicotinoids; Western states accounted for 69,700 acres (40% of all acres treated), Southern States accounted for 75,600 acres (44%), and Western states accounted for 27,600 acres (16%) (Table 3). Additionally, West growers had higher concentrated usage for imidacloprid (42 PCT) and dinotefuran (17 PCT), Southern growers relied more on imidacloprid (16 PCT) and North/Midwest growers also relied more on imidacloprid (12 PCT) for pest management (MRD 2013-2017). Nationally, imidacloprid (21 PCT) was the only neonicotinoid to surpass 10 PCT (Table 2).

Table 3 depicts the stages of the crop development growers usually apply neonicotinoids. Forty percent of all acres are treated prior to crop emergence and approximately an equal amount is treated between crop emergence and when the plants begin to vine. The 'vining to harvest' stage (21% of all acres treated) includes a period prior to the onset of blossoms; cucurbits may continue to bloom throughout the season.

Table 3. Annual Average Cucurbit Acres Treated with Neonicotinoids[2], by Crop Stage, 2013-2017.

Region	Prior to Crop Emergence [1]	Emergence to Vining	Vining to Harvest[3]	Total Acres Treated
West	27,500	34,900	7,400	69,700
South	30,200	24,400	21,000	75,600
North/Midwest	11,600	8,500	7,400	27,600
U.S.	**69,200**	**67,900**	**35,800**	**173,000**

Source: MRD (2013-2017). Numbers may not add up due to rounding.

1 Includes periods prior-to-plant, at-plant, and between planting and crop emergence. Does not include usage of treated seeds.

2 Clothianidin, dinotefuran, imidacloprid, and thiamethoxam altogether.

3 Vining to Harvest includes pre-bloom and bloom-time period for the cucurbits.

BENEFITS OF NEONICOTINOIDS

The benefits of neonicotinoid use on cucurbits are measured in comparison to the next best available pest control option in terms of increased pest control costs per acre (based on market research data) or, if appropriate, losses in yield or quality of product or other measures (i.e. revenue losses, crop rejections by buyers). BEAD first identifies the primary pests targeted by growers when using a neonicotinoid insecticide, by crop stage, using available pesticide market research data. Survey respondents may identify multiple pests for a single application. Respondents may identify pests by scientific name or common name and names can differ by region of the country. Further, single applications may include multiple active ingredients (a.i.), either pre-mixed products or tank-mixes on farm, to target multiple pests. Extension recommendations and professional judgement are used to verify the neonicotinoid target pests and group them appropriately. Alternative pest control options are identified using the same market research data as well as state university extension recommendations.

Target Pests

According to the available pesticide market research data (2013-2017), whiteflies and aphids are the primary cucurbit pests targeted by the neonicotinoids, especially in the West and South, with cucumber beetle the primary pest targeted and aphids the secondary pest in the North/Midwest. These pests are problems throughout the season; as indicated in Table 4 below, growers may make multiple applications of neonicotinoids over the course of the season. In many situations, growers target these pests and other pests simultaneously, as neonicotinoids are effective on a broad spectrum of pests. For example, surveyed Western growers applied at least one neonicotinoid to control for whiteflies (disease vectoring insect) on 60% of the 7,400 acres from vining to harvest, and may have simultaneously treated for aphid on 49% of the 7,400 acres; or made those applications separately (Table 4).

Table 4. Neonicotinoid[1] Usage in Cucurbits, by Region, Target Pest and Crop Stage, 2013-2017.

Pest	Prior to Crop Emergence[2]	Emergence to Vining	Vining to Harvest[3]
West	27,500 acres treated[4]	34,900 acres	7,400 acres
Aphid	61% (of acres treated)[5]	64%	49%
Whitefly	60%	52%	60%
South	30,200 acres	24,400 acres	21,000 acres
Aphid	42%	37%	59%
Whitefly	52%	56%	48%
Cucumber Beetle	9%	18%	13%
North/Midwest	11,600 acres	8,500 acres	7,400 acres
Aphid	39%	56%	71%
Cucumber Beetle	98%	78%	67%

Source: MRD (2013-2017). Total percentages can exceed 100% because multiple pests may be targeted with a single application. Area may not sum due to rounding.

[1] Clothianidin, dinotefuran, imidacloprid, and thiamethoxam altogether.

[2] Includes periods prior to plant, at-plant, and between planting and crop emergence.

[3] Vining to Harvest includes pre-bloom and bloom-time period for the cucurbits.

[4] Acres treated = acres = number of crop-acres treated for the corresponding region and timing. For example, Western growers applied neonicotinoids to 27,500 acres during pre-emergence.

[5] Percent of treated crop-acres that targeted a regional pest during a crop stage. For example, 60% of neonicotinoid-treated acres in the West during pre-emergence targeted whiteflies.

Whitefly (*Bemisia tabaci*, *B. tabaci* Biotype B, *Trialeurodes vaporariorum*) and **Aphid** (*Aphis gossypii*, *A. spiraecola*, *A. fabae*, *A. craccivora*, *Myzus persicae*, *Macrosiphum euphorbiae*, and others)

There are numerous species of both whiteflies and aphids that damage cucurbit crops. From both pests, economic damage to cucurbits may be a result of direct feeding causing the plant to wilt and die under heavy infestation, as well as excessive sooty mold growth due to pest honeydew excretions, and disease transmission (UC IPM 2016a; Mossler 2015).

In the West, whitefly pest pressure can vary based on proximity to, in location or planting time, preferred whitefly hosts, such as cotton or melons (Castle et al. 2009). In the South, whiteflies are a cyclical pest with population booms and busts correlated with years that have warm winters or low rainfall (Dawson 2016) and are most likely to infest cucurbits after cotton burndown. Disease is a primary concern, especially during the fall crop. Whiteflies transmit plant viruses and several physiological disorders of economic importance, namely cucurbit yellow stunting disorder virus (commonly referred to as CYSDV) and silverleaf disorder (Webb et al. 2015). CYSDV-infected plants show yellow spotting, leaf rolling, and fruit has low sugar levels resulting in an unmarketable product (UC IPM 2008). CYSDV can cause up to 70% yield loss in watermelon, cantaloupe, and squash production due to lower fruit quality (Palumbo 2017; Webb et al. 2015). Thus, across all regions, there is a zero-tolerance threshold for whiteflies from growers because even one whitefly can convey a plant disease resulting in high crop loss (Palumbo 2015; Palumbo 2017; UC IPM 2016a, Dawson 2016). In general, foliar insecticide sprays disrupt prolonged whitefly feeding and thus prevent disease transmission in whiteflies (Webb et al. 2015).

Crop loss from aphids is more likely to be due to direct damage or prevalence of sooty mold but they also transmit crop diseases. Unlike whiteflies, aphid virus transmission occurs non-systemically (i.e., potential for rapid infection from probing rather than feeding) and thus insecticide sprays are not completely effective in disease control and may even increase disease spread by encouraging insect movement (Larson et al. 2014; Mossler 2015; UC IPM 2016b). Such viruses can result in quality loss or in some cases, yield loss.

Cucumber beetles (*Diabrotica undecimpunctata*, *Acalymma trivittatum*, *Diabrotica balteata*)

Cucumber beetles are a pest of concern across the cucurbit growing regions but are regionally prevalent in the North/Midwest production area. Beetle larvae feed on roots of cucurbit plants and may cause stand reduction (UC IPM 2016c). Adult beetles feed on leaves, stunt plant growth, spread bacterial wilt, reduce fruit production, and scar fruit (MSU 2017; UC IPM 2016c).

West, Potential Alternatives to and Benefits of Neonicotinoids

In the absence of neonicotinoid insecticides, Western cucurbit growers relying on them would have to use alternative insecticides for their pest control needs. As noted in Table 5, aphids and whiteflies are the primary targets of neonicotinoid usage in the West. Table 5 presents the most commonly used insecticides that target the same pests as the neonicotinoids during the different crop stages in the West. Table 5 also provides the average cost per acre according to the available pesticide market research data.

Table 5. Pesticides Used for Neonicotinoid Target Pests in Western Cucurbits.

Pest	Total Acres Treated [1]	Active Ingredient	Percent of Total Acres Treated [2]	Average Cost ($/acre)
Prior to Crop Emergence				
Aphid	18,000	**Imidacloprid**	80%	$13
		Dinotefuran	7%	$35
		Cyantraniliprole	7%	$81
		Thiamethoxam	3%	$30
Whitefly	16,700	**Imidacloprid**	80%	$13
		Dinotefuran	17%	$35
		Cyantraniliprole	2%	$81
Crop Emergence to Vining				
Aphid	36,400	**Imidacloprid**	37%	$13
		Thiamethoxam	15%	$22
		Dinotefuran	9%	$32
		Acetamiprid	6%	$25
		Chlorantraniliprole	5%	$24
		Cyantraniliprole	3%	$58
Whitefly	39,900	**Dinotefuran**	33%	$32
		Acetamiprid	15%	$25
		Thiamethoxam	8%	$22
Vining to Harvest				
Aphids	60,600	Acetamiprid	39%	$21
		Bifenthrin	22%	$4
		Flonicamid	11%	$23
		Methomyl	5%	$22
		Imidacloprid	3%	$9
Whitefly	46,900	Acetamiprid	31%	$21
		Bifenthrin	23%	$4
		Spiromesifen	9%	$22
		Cyantraniliprole	7%	$51
		Dinotefuran	6%	$23

Source: MRD (2013-2017)

[1] Total area regionally, across all pesticides, treated for the pest during the period, including multiple applications to the same acre.

[2] Percent of regional acres treated, differentiated by application timing, includes pre-mixed products and tank mixes with other active ingredients.

Currently, extension publications recommend up to three applications of neonicotinoids, primarily dinotefuran to control whiteflies and prevent CYSDV across the season (Palumbo 2017). Dinotefuran is recommended at-plant with two subsequent applications during the emergence-to-vining (Palumbo 2017). According to pesticide market research data (2013-2017), imidacloprid is the most commonly used insecticide prior to crop emergence; dinotefuran may be more commonly applied in the emergence-to-vining period.

For both aphids and whiteflies, pre-plant applications of neonicotinoids are reliable for pest control due to their systemic mode of action that protects against pest colonization. Based on extension recommendations from the Western region, alternatives to the neonicotinoids at the pre-plant stage include other systemic active ingredients like cyantraniliprole and flupyradifurone (UC IPM 2016a; Palumbo 2017). Both were registered for use on cucurbits during the period of study, so there is limited reported usage for aphids and whiteflies at this time. Currently, the cost of cyantraniliprole is substantially higher (greater than $50/acre) than for the neonicotinoids (all less than $35/acre).

After crop emergence, growers make insecticide applications as-needed. Available insecticides include several modes of action including neonicotinoids, carbamates, pyrethroids, organophosphates, and insect growth regulators (Castle et al. 2009; Palumbo 2017). During the emergence to first bloom period, three insecticide applications are recommended including an in-furrow or drip application followed by two foliar sprays (Palumbo et al. 2017). Extension recommendations suggest neonicotinoids, namely dinotefuran, for any one or more of these three recommended applications (Palumbo 2017) which corresponds with the usage data in Table 5. Possible alternatives to neonicotinoids as recommended by extension include: acetamiprid, cyantraniliprole, methomyl, oxamyl, or dimethoate (Palumbo 2017). Applications of methomyl, oxamyl, or dimethoate would not be standalone applications but may be tank-mixed with a pyrethroid (e.g., bifenthrin) for improved knockdown efficacy (Palumbo 2017). Many of these alternatives are currently used, especially in the later part of the season; a grower's ability to use them in place of neonicotinoids between emergence and vining may be limited due to seasonal restrictions on rates or frequency of applications.

Table 6 presents a partial budget analysis to quantify the benefits of neonicotinoids, based on a crop budget for fresh cantaloupe from the University of California (Mayberry and Meister, 2003). Costs are inflated about 29% to account for inflation[2], based on the Consumer Price Index (BLS, 2018). This scenario is chosen to represent the benefits of neonicotinoids in the West since cantaloupe is a common cucurbit produced in the West. Gross revenue is for all cucurbits; see Table 1.

As a baseline scenario, BEAD models an application of imidacloprid at-plant, followed by two other neonicotinoid applications in the period between emergence and vining, with one of the two applications possibly early in the vining-to-harvest period. Based on costs shown in Table 6, neonicotinoid-only insecticide costs would be about $70 per acre. In the absence of neonicotinoids, growers would have to rely on one of the newer chemistries for aphid and whitefly control prior to crop emergence, such as cyantraniliprole or flupyradifurone, which could cost about $80 per acre, and other insecticides for subsequent applications. Options such as acetamiprid in combination with bifenthrin are similar in price to dinotefuran, but somewhat more expensive than imidacloprid and thiamethoxam; cyantraniliprole is generally more expensive.

Extension recommendations cited above indicate that these alternatives are effective and yield loss would not be anticipated. This analysis indicates that use of neonicotinoids saves growers as

[2] Costs were calculated from January 2003 to January 2015. 2015 was chosen as the end year to ensure that the mid-point coincides with Gross Revenue.

much as $95 per acre in chemical costs (last column, Table 6); loss of neonicotinoids could reduce net operating revenue about 5%. Much of this benefit is derived from the at-plant usage. Chemical costs would increase about $30 to replace post-emergence neonicotinoid usage (third column, Table 6).

Table 6. Impacts of Neonicotinoid Restriction in Western Cucurbit Production

	Baseline [1]	with alternatives post-emergence [2]	with alternatives pre- and post-emergence [3]
Gross Revenue	$5,300	$5,300	$5,300
Operating Costs	$1,240	$1,240	$1,240
Insecticide Costs, whitefly & aphid[4]	$70	$100	$165
Harvest Costs	$2,170	$2,170	$2,170
Net Operating Revenue	**$1,820**	**$1,790**	**$1,725**
	Loss per Acre	$30	$95
	Percent change in net operating revenue	-2%	-5%

Source: Table 2; Mayberry and Meister, 2003 (adjusted for inflation).
Numbers may not sum due to rounding.

1 Baseline insecticide costs assume one imidacloprid application prior to emergence costing about $15/acre and two subsequent applications of neonicotinoids, *e.g.*, thiamethoxam and dinotefuran, at about $22/acre and $32/acre, respectively.

2 Assuming one imidacloprid application prior to emergence costing about $15/acre. Post-emergence neonicotinoid applications replaced by acetamiprid with bifenthrin ($25/acre) and cyantraniliprole ($60/acre) or similar priced chemical.

3 Pre-emergence neonicotinoid application replaced by cyantraniliprole ($80/acre). Post-emergence applications utilizing acetamiprid with bifenthrin ($25/acre) and cyantraniliprole ($60/acre) or similar priced chemical.

4 Insecticide costs only include neonicotinoids and substitutes for the neonicotinoids and focuses on the main pests, whiteflies and aphids.

Under heavy pest pressure, the absence of neonicotinoids could constrain grower's ability to achieve season-long control since applications may be necessitated on four to six-day intervals. Even under normal conditions, growers may have to increase reliance on organophosphates (OP) like dimethoate or carbamates such as methomyl to rotate between chemistries and maintain a resistance management program. Additionally, if the use of bifenthrin, a pyrethroid, triggered an outbreak of mites, more miticide applications may be necessitated increasing control costs in the absence of nitroguanidine neonicotinoids.

South, Potential Alternatives to and Benefits of Neonicotinoids

The pest situation in the South is like that of the West, however, the insecticides currently in use are somewhat different. There are no reports of growers using acetamiprid, one of the likely alternatives to the neonicotinoids in the West (MRD 2013-2017). *Chenopodium ambrosioides* (a biochemical pesticide) seems to play a similar role in the South as in the West, and chlorantraniliprole is more commonly used than cyantraniliprole (Table 7). Some usage of flupyradifurone, even given the recent registration, is reported in the later crop stages (MRD 2013-2017).

Table 7. Pesticides Used for Neonicotinoid Target Pests in Southern Cucurbits.

Pest	Total Acres Treated[1]	Active Ingredient	Percent of Total Acres Treated[2]	Average Cost ($/acre)
Prior to Crop Emergence				
Aphid	13,600	**Imidacloprid**	84%	$12
		Thiamethoxam	11%	$20
		Chlorantraniliprole	3%	$30
Whitefly	19,600	**Imidacloprid**	53%	$12
		Thiamethoxam	28%	$20
		Chlorantraniliprole	12%	$30
Crop Emergence to Vining				
Aphid	25,000	**Imidacloprid**	25%	$8
		Chlorantraniliprole	16%	$29
		Ch. Ambrosioides	14%	$21
		Thiamethoxam	7%	$19
		Dinotefuran	5%	$29
Whitefly	45,300	**Dinotefuran**	21%	$29
		Chlorantraniliprole	18%	$29
		Ch. Ambrosioides	11%	$21
		Spiromesifen	8%	$19
		Imidacloprid	7%	$8
Vining to Harvest				
Aphids	54,100	*Ch. Ambrosioides*	34%	$21
		Imidacloprid	18%	$9
		Pymetrozine	7%	$19
		Spiromesifen	4%	$21
		Dinotefuran	3%	$24
		Chlorantraniliprole	3%	$32
Whitefly	81,900	*Ch. Ambrosioides*	23%	$21
		Chlorantraniliprole	15%	$32
		Imidacloprid	7%	$9
		Pymetrozine	6%	$19
		Flupyradifurone	5%	$25

Source: MRD (2013-2017)

1 Total area regionally, across all pesticides, treated for the pest during the period, including multiple applications to the same acre.

2 Percent of acres treated during the respective crop stage and for primary pest, includes tank mixes with other products.

As in the West, extension (Walgenbach, 2018) recommendations in the Southern U.S. state that at least three applications of insecticides are needed[3]; BEAD postulates an application of imidacloprid at-planting and one post-emergence application of dinotefuran and thiamethoxam (each to control for aphids and whiteflies) for an overall annual cost of $60 per acre (Table 8).

[3] Confirmed from 14-day intervals (Walgenbach, 2018) and cucumber growing season (50-day planting-to-harvest) [Polk et al., 2015], also 3-insecticide application aphid/whitefly control program (Bayer CropScience, 2017).

Other production costs are derived from Fonsah and Shealy (2011) for cucumber production, one of the more common cucurbits grown in the South (Table 8). Given average gross revenue, from Table 1, growers are estimated to make about $1,340 per acre in net operating revenue, *i.e.*, before fixed costs are considered. Potential alternatives for post-emergence control of whitefly and aphid include chlorantraniliprole and flupyradifurone, which are similar in cost to thiamethoxam and dinotefuran. Chlorantraniliprole may be the most likely pre-emergence alternative to imidacloprid; it costs about $30 per acre, or about $20 per acre more than imidacloprid (Table 7). Under this scenario, the benefits of neonicotinoid use are relatively modest, in comparison to the situation in the West (Table 8). As noted previously, however, growers may find it more difficult and costlier to achieve season-long control of whitefly and aphid pests without neonicotinoids if the identified alternatives cannot be used due to seasonal limits or for resistance management concerns.

Table 8. Impacts of Neonicotinoid Restriction in Southern Cucurbit Production

	Baseline [1]	with alternatives post-emergence [2]	with alternatives pre- and post-emergence [3]
Gross Revenue [4]	$4,060	$4,060	$4,060
Operating Costs	$835	$835	$835
Insecticide Costs, whitefly & aphid	$60	$66	$84
Harvest Costs	$1,825	$1,825	$1,825
Net Operating Revenue	**$1,340**	**$1,334**	**$1,316**
	Loss per Acre	$6	$24
	Percent change in net operating revenue	Less than -1%	-2%

Source: Tables 2 and 7; Fonsah and Shealy, 2011. Numbers may not sum due to rounding.

1 Baseline insecticide costs assume one imidacloprid application prior to emergence costing about $12/acre and two subsequent applications of neonicotinoids, thiamethoxam ($19/acre) and dinotefuran ($29/acre).

2 Insecticide costs assume one pre-emergence imidacloprid application ($12/acre) and post-emergence neonicotinoid applications replaced by flupyradifurone ($25/acre) and chlorantraniliprole ($29/acre) or similar priced chemical.

3 Pre-emergence neonicotinoid application replaced by chlorantraniliprole ($30/acre); post-emergence neonicotinoid applications replaced by flupyradifurone ($25/acre) and chlorantraniliprole ($29/acre) or similar priced chemical.

4 Insecticide costs only include neonicotinoids and substitutes for the neonicotinoids and focuses on the main pests, whiteflies and aphids.

North/Midwest, Potential Alternatives to and Benefits of Neonicotinoids

Aphids represent a similar problem for cucurbit growers in the North/Midwest region as in other regions and growers would likely turn to similar alternatives, e.g., acetamiprid with a pyrethroid, if neonicotinoids were not available for use.

For cucumber beetles, foliar sprays of pyrethroids (e.g., fenpropathrin, esfenvalerate) or carbamates (e.g., carbaryl) alongside pre-plant soil-applied neonicotinoid treatments are common extension recommendations (MSU 2017). During the pre-plant phase of cucurbit production, neonicotinoids are the only active ingredients recommended by extension based on BEAD's search query (for example see, Midwest Vegetable Production Guide for Commercial Growers 2019). In lieu of neonicotinoids at-plant to protect cucurbit roots during the early season, a combination of chlorpyrifos with permethrin or other pyrethroids may be the most likely alternative (MRD 2011-2015). While neonicotinoids at-plant or following emergence would protect cucurbit crops through their systemic mode of action, likely alternatives for cucumber beetle are not systemic. Thus, growers may need additional applications in the growing season; some crop damage may be sustained early in the season without the systemic protection provided by neonicotinoids. During emergence-to-vining, pyrethroids are the most commonly applied alternative to neonicotinoids for cucumber beetle control (Table 9). Pyrethroids are broad spectrum and would control cucumber beetle, aphids, and other pests.

Table 9. Insecticides Used for Neonicotinoid Target Pests, North/Midwest Cucurbits

Pest	Total Acres Treated [1]	Active Ingredient	Percent of Total Acres Treated [2]	Average Cost ($/acre)
Prior to Crop Emergence				
Aphid	5,800	**Imidacloprid**	73%	$16
		Permethrin	14%	$4
		Carbaryl	5%	$7
		Chlorpyrifos	5%	$11
Cucumber Beetle	13,900	**Imidacloprid**	77%	$16
		Pyrethroids	15%	$4
		Thiamethoxam	4%	$19
Crop Emergence to Vining				
Aphid	10,900	**Imidacloprid**	28%	$11
		Spiromesifen	26%	$25
		Acetamiprid	7%	$23
		Chlorantraniliprole	4%	$31
Cucumber Beetle	53,900	Pyrethroids	71%	$4
		Imidacloprid	8%	$11
		Spiromesifen	5%	$25
Vining to Harvest				
Aphids	31,900	Pyrethroids	59%	$5
		Thiamethoxam	11%	$11
		Malathion	6%	$6
		Acetamiprid	5%	$27
Cucumber Beetle	92,300	Pyrethroids	87%	$5
		Thiamethoxam	3%	$11
		Chlorantraniliprole	3%	$27

Source: MRD (2013-2017)

1 Total area regionally, across all pesticides, treated for the pest during the period, including multiple applications to the same acre.

2 Percent of acres treated includes tank mixes with other products.

Using the chemical costs from Table 9, BEAD calculated that the baseline insect pest management program[4] would cost about $40/acre per year, on average.

The Gross Revenue for North/Midwest was $2,640 (Table 1), but since pickling cucumber (mostly grown in the North/Midwest) accounts for almost 70% of the cucumber acreage and less than half the total value of cucumber production nationally (USDA/NASS, 2018), BEAD is not using this Gross Revenue calculation. BEAD is using the pumpkin Gross Revenue ($2,890/acre) from Table 1 as the representative crop in the analysis because pickling cucumber significantly lowers the Gross Revenue for the North/Midwest.

The Operating and Harvest costs come from a 2014 pumpkin (plasticulture) budget report by Penn State (PSU, 2014). BEAD did not use the marketing costs because the budget report states "Pumpkins sold retail either pick-your-own or through your roadside market", thus omitting the marketing costs. Therefore, the pumpkin growers' Net Operating Revenue is a gain of $110/acre. Some pumpkin growers may experience losses on the sale of their pumpkins, they can offset losses by supplementing their income offering agro-tourism programs (UCCE, 2019; Olivo, 2018; Young, 2018).

When restricting neonicotinoids during post-emergence, the likely alternatives would be chlorantraniliprole and acetamiprid with a pyrethroid (Table 10). This treatment program has one application of imidacloprid pre-emergence and chlorantraniliprole and acetamiprid with a pyrethroid post-emergence; which would cost about $75/acre, or $35/acre premium over the baseline. This would reduce the Net Operating Revenue to $75, or a 32% loss. If neonicotinoids were restricted, then the treatment would consist of a chlorpyrifos/pyrethroid mixture pre-emergence and spiromesifen and acetamiprid for post-emergence applications. The program is estimated to be $70/acre, which is a $30/acre premium over the baseline (Table 10). The alternatives program assumes one-for-one substitutions, and BEAD cannot determine the effects on crop yield, therefore BEAD assumes the same historical yield.

Table 10. Impacts of Neonicotinoid Restriction in North/Midwest Cucurbit Production

	Baseline [1]	with alternatives post-emergence [2]	with alternatives pre- and post-emergence [3]
Gross Revenue	$2,890	$2,890	$2,890
Operating Costs	$1,780	$1,780	$1,780
Insecticide Costs, cucumber beetle & aphid	$40	$75	$70
Harvest Costs	$960	$960	$960
Net Operating Revenue	**$110**	**$75**	**$80**
Loss per Acre		$35	$30
Percent change in net operating revenue		-32%	-27%

[4] Baseline insecticide costs assume one pre-emergence imidacloprid application ($16/acre) and two subsequent applications of thiamethoxam ($11/acre each)

Source: Table 2; PSU (2014). Numbers may not sum due to rounding.
[1] Baseline insecticide costs assume one imidacloprid application prior to emergence costing about $16/acre and two subsequent applications of thiamethoxam at around $11/acre each.
[2] One imidacloprid application pre-emergence ($16/acre). Post-emergence applications are chlorantraniliprole ($30/acre) and acetamiprid with a pyrethroid ($30/acre) and or similarly priced chemicals.
[3] Chlorpyrifos and a pyrethroid ($16/acre) pre-emergence application, plus additional applications of spiromesifen ($25/acre) and acetamiprid ($27/acre) in the post-emergence period.

The benefits of the neonicotinoids for North/Midwest cucurbit growers is shown in Table 10. In addition to lower program costs, growers rely on the neonicotinoids for the broad-spectrum activity and systemic properties. The alternatives have a narrower pest spectrum relative to the neonicotinoids, and in some cases, lower efficacy on the primary pest – cucumber beetle. According to University of Minnesota Extension (2018), the cucumber beetle larvae feed on the roots and underground portions of the stem and adults feed on the foliage, therefore, this analysis includes pre- and post-emergence applications. In this analysis, BEAD assumed equivalent efficacy when replacing a neonicotinoid one-for-one basis.

Impacts of Risk Mitigation Options

As explained in the Background section, use of neonicotinoids poses various potential risks to non-target organisms. Options to address those risks include:

- reducing the maximum single application rate;
- reducing the maximum annual application rate;
- prohibiting applications during the period prior to bloom;
- prohibiting foliar applications; and
- requiring drift mitigation in the form of larger droplets.

This section discusses the potential impacts of these mitigation measures on cucurbit growers.

Reduction in Maximum Single Application Rates

BEAD presents a combined table (Table 11) to show labeled maximum single and yearly application rates for foliar and soil applications. In this analysis, BEAD concentrated on foliar applications because almost all soil applications are made once per year, based on the single and annuals labeled application rates (Table 11).

Table 11. Neonicotinoid Application Limits on Cucurbits (Crop Group 9)

Active Ingredient	Application Method	Maximum Single Application Rate (lbs. a.i./acre)	Maximum Yearly/Seasonal Application Rate (lbs. a.i./acre)
Clothianidin	Foliar	0.067	0.200
	Soil	0.200	0.200
Dinotefuran	Foliar	0.179	0.263
	Soil	0.328	0.523
Imidacloprid[1]	Soil	0.380	0.380

Thiamethoxam[1]	Foliar	0.088	0.172
	Soil	0.172	0.172

Sources: Belay® Label, Venom® Label, Admire® Pro Label, Durivo® Label

[1] Imidacloprid labels do not have instructions for foliar applications.

According to the available pesticide usage data (MRD 2013 – 2017), nationally all four neonicotinoids were used and BEAD presents actual neonicotinoid application rates[5], both soil and foliar applications, for each active ingredient, except imidacloprid which only had soil application instructions.

Cucurbit growers applied clothianidin foliarly (at application rates less than or equal to 0.067 lbs. a.i./A) to 78% of all treated acres, and soil-applied for the remaining 22% of treated acres. About 35% (or 2,000 acres) of all foliarly-treated acres were performed at greater than 0.060 lbs. a.i./A. Approximately 47% (or 600 acres) of all soil-applied acres would be affected by a 10% reduction in the maximum application rate. This indicates that a clothianidin 10% rate drop will have a significant impact on cucurbit growers using clothianidin, with 2,000 foliarly-treated acres and 600 soil-treated acres being affected. (MRD 2013-2017)

Regarding dinotefuran, cucurbit growers opted to mostly apply it foliarly, accounting for two-thirds of all dinotefuran-treated acres, and soil application make up the other one-third (MRD 2013-2017). Growers chose to apply dinotefuran at or near the foliar labeled limit (Table 11) on 46% of foliarly-treated acres and applied dinotefuran at or near 0.267 lbs. a.i./A on 97% of soil-treated acres (MRD 2013-2017). Thus, a 10% rate reduction would have a significant impact on growers using dinotefuran foliarly (16,900 acres), not so much for those using soil-applications (no affected acres). However, a 20% rate reduction to 0.262 lbs. a.i./A would impact more than 90% of soil-treated acres of dinotefuran. (MRD 2013-2017)

Imidacloprid applications were done at rates in distinct groups, for example, 38% of the acres (or 38,400 acres) treated were done at rates between 0.24 - 0.29 lbs. a.i./A, and 26% (or 26,500 acres) between 0.35 - 0.38 lbs. a.i./A. If a rate reduction of 10% to 0.342 lbs. a.i./A were proposed, just under 29%, or 28,700 acres, of imidacloprid-treated acres would be affected. (MRD 2013-2017)

Cucurbit growers applied thiamethoxam foliarly to 38% of all cucurbit treated acres, and soil-applied for the remaining 62% of acres treated. More than 91% (or 10,500 acres) of all foliarly-treated acres were performed at less than 0.053 lbs. a.i./A and 75% of all soil-applied acres were treated at rates greater than 0.163 lbs. a.i./A. A foliar rate reduction of 10% would affect 7% (or 800 acres) of all foliarly-treated acres and a soil rate reduction of 10% would affect 75% (or 14,100 acres) of all soil-treated acres. (MRD 2013-2017)

The relatively (to the labeled limit) high foliar application rates indicate that growers will be significantly impacted by an application rate reduction, across all the neonicotinoids. In all, about 19,700 foliar-treated and 29,000 soil-applied acres would be affected by a 10% rate reduction. Growers unable to effectively control the pests targeted by the neonicotinoids at the lower

[5] All application rates were performed using MRD from 2013-2017, then BEAD aggregated the usage parameters (total acres treated, pounds applied, and application rates) to provide a sufficient sample size.

application rate may need to use other insecticides. The per-acre premiums range from $24 to $95 for alternative pesticide applications, or between a 2% and 27% reduction in net operating revenue.

Application rate reductions for neonicotinoids may be equivalent to a cancellation[6] because higher application rates are needed to control pests, particularly in areas with known resistance issues (e.g., Arizona, Florida). In the long term, rate reductions for the neonicotinoids might cause resistance issues for other active ingredients that will be used more frequently (e.g., acetamiprid already has a FIFRA Section 24(c) for double the application rate in Arizona because of whitefly resistance).

Reduction in the Maximum Annual Application Rate

In lieu of explicitly reducing the number of applications per year, EPA is considering a reduction in the foliar and soil maximum annual application rates for each of the four neonicotinoids. Based on the label maximum single application rate and annual application rate for foliar applications of the neonicotinoids (Table 11), cucurbit growers can apply clothianidin foliarly three times a year at the maximum single application rate, dinotefuran twice per year at the maximum single application rate, and thiamethoxam twice annually at the maximum single application rate. Imidacloprid's label does not specify any distinction between foliar and soil application rates (Table 11). BEAD assumed that the single and annual maximum applications are the same, therefore imidacloprid can only be applied once per year/season at the maximum single application rate.[7] Therefore, any annual application rate reduction can be treated as a reduction in the number of times the neonicotinoids can be applied foliarly at the maximum single application rate, and in the case of imidacloprid, there would not be any change (stays at 1 per year/season) to the number of applications per year/season.

On average, over the years 2013-2017, cucurbit growers applied clothianidin about 1.3 times per year/season, with the highest recorded being cantaloupe growers applying twice per year/season. Cucurbit growers applied dinotefuran 1.5 times per year/season, and cucumber growers applied most frequently at 1.8 times per year/season. Cucurbit growers applied imidacloprid and thiamethoxam 1.2 times per year/season, with watermelon growers applying imidacloprid 1.5 times per year/season and pumpkin growers applying thiamethoxam 1.7 times per year/season. (MRD 2013-2017)

Reducing the maximum annual application rate might impact growers requiring season-long treatments or when a primary pest infestation occurs. Additionally, the annual rate reduction would limit growers' access to systemic active ingredients, which some of the potential alternatives are not. Based on the available pesticide usage data, a 10% reduction in the annual

[6] This would be a default "cancellation" because growers are already using the neonicotinoids near the labeled limit and reducing the application rate would force growers to use the neonicotinoids at lower rate, which might not control the pests as well, possibly leading to crop yield losses due to insect feeding and disease vectoring. Growers might opt to forgo neonicotinoid treatments if pest populations cannot be controlled, thus abandoning the neonicotinoids in favor of other active ingredients recommended.

[7] This assumption may not hold true for all growers. As discussed above, nothing precludes growers from applying at lower rates multiple times.

application rate could impact as many as 14% of the average number of base acres treated with clothianidin per year; 15% of the average number of base acres treated with dinotefuran; more than 25% of the average number of base acres treated with imidacloprid; and more than 50% of the average number of base acres treated with thiamethoxam. (MRD, 2013-2017) Assuming no yield or quality losses, growers who might experience prematurely reaching the maximum annual rate for the neonicotinoids would need to apply other insecticides. As a result, growers could see their application costs increase between $6/acre (Table 8 – with post-emergent alternatives) and $35/acre (Table 10 – with post-emergent alternatives) and their net operating revenue decline by less than 1% (South) to 32% (North).

Prohibiting Applications Pre-Bloom

The proposed mitigation to prohibit neonicotinoid applications in cucurbits to pre-bloom is going to have a significant impact on cucurbit growers, with as much as 20% of the treated acres being affected (Table 12 – Vining to Harvest). If this restriction is enacted, then all Vining to Harvest neonicotinoid treatments will have to be substituted with other chemical treatments. As discussed previously, controlling for cucurbit pests is a season-long endeavor, particularly for whiteflies – growers have a very low pest count threshold – due to disease vectoring. Diseases are a primary concern, especially during the fall crop. Whiteflies transmit plant viruses and several physiological disorders of economic importance, namely CYSDV and silverleaf disorder, leading to infestations and disease spread right before harvest – a devastating prospect to the growers.

The greatest impact could be on cucurbit producers in the South, where treatments after vining are more common. If neonicotinoids are only available pre-bloom and all subsequent neonicotinoid applications ceased, growers would have no choice but to use the likely alternatives. Therefore, the treatment program includes one neonicotinoid application for the first application, then using alternatives thereafter. Assuming no yield or quality losses, on average, a Western grower's pest control costs could increase $30/A (or 2% loss in net operating revenue); a Southern grower's pest control costs could increase $6/A (or less than 1% loss in net operating revenue); and a North/Midwest grower's pest control costs could increase $35/A (or 32% loss in net operating revenue)[8].

Prohibiting Foliar Applications

This restriction could result in an overhaul of multiple cucurbit pest management programs because the neonicotinoids can be foundational to protecting crops from insect pests and to prevent disease-vectoring. Without the ability to foliarly apply the neonicotinoids, BEAD concludes that treatment programs would need to change dramatically, growers are unlikely to have access to a similarly systemic insecticides, and increased pesticide costs are probable.

Altogether, foliar applications are conducted on 65,600 acres (or 38% of all treated acres), which represents a considerable amount of cucurbit acres affected (Table 12). Growers' losses could amount to $95/acre in the West, $24/acre in the South, and $30/acre in the North/Midwest; or in terms of net operating revenues, a loss of 5%, 2%, and 27%, respectively. BEAD concludes that a foliar application prohibition would severely impact cucurbit growers, especially from

[8] All regional cost increases come from Tables 6, 8, and 10 – "with alternatives post-emergence"

emergence-to-harvest (Table 12). Additionally, pest populations could flare up in the latter stages of the crop growth cycle, leading to application of another insecticide at a higher cost or crop yield and quality significantly affected.

Table 12. Neonicotinoid Usage on Cucurbits, by Crop Stage and Application Method

Crop Stage	TAT	Percent of TAT
Prior to Emergence (soil application)	69,200	40
Emergence to Vining		
Ground/Air applied (foliar application)	34,300	20
Chemigation (likely soil application)	33,600	19
Vining to Harvest		
Ground/Air applied (foliar application)	31,300	18
Chemigation (likely soil application)	4,500	2
Total	173,000	100

Source: MRD, 2013-2017

Mandating Droplet Size

The Agency is considering establishing a mandatory droplet size of medium-to-coarse for all neonicotinoids to address the potential risks of neonicotinoids to terrestrial invertebrates. Components of applications, including droplet size, are complex, but essentially insects need to have contact with, or ingest, a lethal dose of insecticide to be effectively controlled which requires proper coverage throughout the plant. Hypothetically, systemic insecticides, like neonicotinoids, might control some insects with a larger droplet size requirement due to the systemic movement within the plant, but systemic activity alone does not mean effective control will still occur. Buchholz and Nauen (2001) showed that the control from neonicotinoids was more complex than an active ingredient being systemic, i.e., control was a "combination of systemic and contact properties." The authors indicate that factors such as the cuticular properties of leaves, metabolism and stage of insect (e.g., mobile versus quiescent stages), and the physio-chemical properties of the insecticide contribute to the performance of neonicotinoids. Furthermore, Basso et al. (2016) showed that contact with neonicotinoids was needed to control insects on large plants compared with smaller plants, presumably due to poor translocation in large plants.

Generally, entomologists accept that good coverage is required for maximum efficacy during an application and that fine droplets provide better coverage than coarse droplets. BEAD expects that droplet size restrictions could impact the control of pests that are controlled by contact with neonicotinoids. If control was reduced, BEAD anticipates growers would increase rates, make more frequent applications, and/or select alternative products (pyrethroids, carbaryl or diflubenzuron, depending on the target pest). Additionally, growers may face financial impacts due to increased cost of applications and/or reduced yields or quality due to poor control. Furthermore, mandatory droplet size could lead to poor coverage which could expose target pest to ineffective rates in the field and undermine resistance management efforts.

Specifically, BEAD is concerned that systemic activity may not adequately control the primary and secondary pests quickly enough to prevent injury or disease vectoring. BEAD expects Western growers would be disproportionately affected if poor coverage affected efficacy because Western growers have the highest cucurbit yield (by weight) and Gross Revenue per acre. The Western growers plant more of higher-valued crops (cantaloupes and watermelons – see Table 1) and would be more affected than Southern and North/Midwest growers because whitefly disease vectoring causes the crop to be unmarketable.

UNCERTANITIES

As with any broad, quantitative analysis, growers in different states, but within a region, may experience different impacts than the calculated impacts described above, especially when using aggregated regional gross revenue and individual crop budgets.

From the available pesticide market research data, BEAD could not conclusively differentiate between soil and foliar applications but made an attempt to characterize the usage from labeled application rates and application rates based on the usage data. There were instances of small sample sizes in the pesticide usage data, which BEAD omitted from the analysis.

BEAD may have underestimated the likelihood of increased disease pressure from insect-vectored pathogens transmitted by whiteflies that are controlled by systemic insecticides when systemic alternatives are not available, or label maximum use has been exhausted. The alternative pest management regimen may require non-systemic alternatives which could reduce control of the primary pests. Additionally, the alternatives may not cover the full spectrum of pests and crops as the neonicotinoids. Some proposed restrictions would impact the resistance management program, possibly leading to future resistance issues.

CONCLUSION

Overall, 401,000 acres of cucurbits are harvested, on average, with cucumbers and watermelon the largest in terms of acreage. The total value of cucurbit production averages almost $1.6 billion annually; watermelon alone accounts for almost one-third of the total value. Additionally, cucurbits are grown throughout the United States, but production is regionally concentrated in the West, South, and North/Midwest regions.

Cucurbit growers treated 173,000 acres with neonicotinoids nationally; Western states accounted for 69,700 acres (40% of all acres treated), Southern States accounted for 75,600 acres (44%), and Western states accounted for 27,600 acres (16%). Whiteflies and aphids are the primary cucurbit pests targeted by the neonicotinoids, especially in the West and South, with cucumber beetle the primary pest targeted and aphids the secondary pest in the North/Midwest.

These pests are problems throughout the season, and growers may make multiple applications of neonicotinoids over the course of the season. In many situations, growers target these pests and other pests simultaneously, as neonicotinoids are effective on a broad spectrum of pests. From these pests, economic damage to cucurbits may be a result of direct feeding causing the plant to wilt and die under heavy infestation, as well as excessive sooty mold growth due to pest honeydew excretions, and disease transmission.

The need to use neonicotinoids cannot be understated in cucurbit production areas with CYSDV. CYSDV can cause up to 80% yield loss in watermelon, cantaloupe, and squash production due to lower fruit quality (Abrahamian and Abou-Jawdah, 2014). An emergence-to-vining neonicotinoid restriction could devastate cucurbit growers in the Western production region due to crop diseases like CYSDV. This disease is particularly worrisome because it rots the fruit on the inside and causing a complete economic loss at harvest-time and possible financial ruin as some of the cucurbits are low margin crops. For both aphids and whiteflies, pre-plant applications of neonicotinoids are reliable for pest control due to their systemic mode of action that protects against pest colonization. Even under normal conditions, growers may have to increase reliance on organophosphates (OP) like dimethoate or carbamates such as methomyl to rotate between chemistries and maintain a resistance management program

As in the West, extension (Walgenbach, 2018) recommendations in the Southern states recommend that at least three applications of insecticides are needed. Growers may find it more difficult and costlier to achieve season-long control of whitefly and aphid pests without neonicotinoids if the identified alternatives cannot be used due to seasonal limits or for resistance management concerns.

Cucumber beetles are a pest of concern across the cucurbit growing regions but are regionally prevalent in the North/Midwest production area. Adult beetles feed on leaves, stunt plant growth, spread bacterial wilt, reduce fruit production, and scar fruit, leading to lower market prices or complete economic losses. During the pre-plant phase of cucurbit production, neonicotinoids are the only active ingredients recommended by extension. While neonicotinoids at-plant or following emergence would protect cucurbit crops through their systemic mode of action, likely alternatives for cucumber beetle are not systemic. The alternatives have a narrower pest spectrum relative to the neonicotinoids, and in some cases, lower efficacy on the primary pest – cucumber beetle.

As explained in the Background section, use of neonicotinoids poses various potential risks to non-target organisms. Options to address those risks include:

- reducing the maximum single application rate;
    - Reducing the maximum single application rate would affect growers applying the neonicotinoids at the higher-end of the allowable limit. For instance, a 10% rate reduction is expected to affect: 2,000 foliar and 600 soil applications treated with clothianidin; 16,900 foliar dinotefuran-treated acres; 14,300 soil-applied acres treated with imidacloprid; and 14,100 thiamethoxam-treated, soil-applied acres. Growers unable to effectively control the pests targeted by the neonicotinoids at the lower application rate may need to use other insecticides. The per-acre premiums range from $24 to $95 for alternative pesticide applications, or between a 2% and 27% reduction in net operating revenue.
- reducing the maximum annual application rate;

    - Reducing the maximum annual application rate would likely impact growers requiring season-long treatments or when a primary pest infestation occurs. Overall, a proposed 10% reduction in the annual application rate could impact as many as 14% of the average number of base acres treated with clothianidin per year; 15% of the average number of base acres treated with dinotefuran; more than 25% of the average number of base acres treated with imidacloprid; and more than 50% of the average number of base acres treated with thiamethoxam. Growers who might experience prematurely reaching the maximum annual rate for the neonicotinoids would need to apply other insecticides and their application costs could increase between \$6/acre and \$35/acre.
- prohibiting applications during the period prior to bloom;
    - The proposed mitigation to prohibit neonicotinoid applications in cucurbits to pre-bloom is going to have a significant impact on cucurbit growers, with as much as 20% of the treated acres being affected (or 35,800 acres). If this restriction is enacted, then all Vining to Harvest neonicotinoid treatments will have to be substituted with other chemical treatments. If neonicotinoids are only available pre-bloom and all subsequent neonicotinoid applications ceased, assuming no yield or quality losses, on average, a Western grower's pest control costs could increase \$30/A (or 2% loss in net operating revenue); a Southern grower's pest control costs could increase \$6/A (or less than 1% loss in net operating revenue); and a North/Midwest grower's pest control costs could increase \$35/A (or 32% loss in net operating revenue).
- prohibiting foliar applications; and
    - Altogether, foliar applications are conducted on 65,600 acres (or 38% of all treated acres), which represents a considerable amount of cucurbit acres affected. Growers' losses could amount to \$95/acre in the West, \$24/acre in the South, and \$30/acre in the North/Midwest; or in terms of net operating revenues, loss of 5%, 2%, and 27% respectively. Additionally, pest populations could flare up in the latter stages of the crop growth cycle, leading to applications of another insecticide at a higher cost or reduced crop yield and quality. BEAD concludes that a foliar application prohibition would severely impact cucurbit growers, especially from emergence-to-harvest.
- requiring drift mitigation in the form of larger droplets.
    - The Agency may consider a coarse droplet size to mitigate risks to non-target organisms. BEAD expects that droplet size restrictions could impact the control of pests that are controlled by contact with neonicotinoids. If control was reduced, BEAD anticipates growers would increase rates, make more frequent applications, and/or select alternative products (pyrethroids, carbaryl or diflubenzuron, depending on the target pest). Additionally, growers may face financial impacts due to increased cost of applications and/or reduced yields or quality due to poor control. Furthermore, mandatory droplet size could lead to poor coverage, which could expose target pest to ineffective rates in the field and undermine resistance management efforts.

Replacing neonicotinoids with pyrethroids (e.g., cucumber beetle) may lead to mite outbreaks, warranting the need to make another application to control the outbreak pest. Also, the level of cross-resistance between the nitroguanidine neonicotinoids is unknown; thus, application rate reductions might hasten the development of resistance to these active ingredients nationwide. In the short-term, application rate reductions for neonicotinoids may be equivalent to a cancellation in areas with known resistance issues (e.g., Arizona, Florida). In the long-term, application rate reductions for the neonicotinoids might cause resistance issues for other active ingredients (e.g., acetamiprid already has a 24(c) for double rate in Arizona because of whitefly resistance).

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